SECONDARY HAZARD OF LIVESTOCK PROTECTION COLLARS TO SKUNKS AND EAGLES

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Abstract: We evaluated the potential secondary hazard posed by striped skunks (*Mephitis mephitis*) and golden eagles (*Aquila chrysaetos*) scavenging carcasses of coyotes (*Canis latrans*) killed by Livestock Protection Collars (LPC's). These collars are filled with a formulation of Compound 1080 registered with the U.S. Environmental Protection Agency. Skunks and eagles were fed diets containing 4.1 and 7.7 ppm 1080, respectively, for 5 days. Although the treated diets contained 2–3 times the highest concentration of 1080 detected in carcasses of coyotes killed by LPC's, no deaths occurred. Some eagles showed signs of 1080 intoxication including loss of strength and coordination, lethargy, and tremors. Both species reduced consumption of treated diets but resumed normal feeding on untreated diets within a few days. We conclude that consuming carcasses of coyotes killed by LPC's poses little, if any, hazard to striped skunks or golden eagles.

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In July 1985, the U.S. Environmental Protection Agency registered Compound 1080 (sodium fluoroacetate) for use in Livestock Protection Collars (Reg. No. 56228-22). Collar use is limited to certified applicators for controlling coyote predation on sheep and goats (Moore 1985). Livestock Protection Collars (LPC's) are devices which include black rubber packets containing a Compound 1080 solution. The LPC's can be attached to the throats of sheep and goats. When coyotes attack collared livestock with characteristic bites to the throat, they puncture the packets and ingest a lethal dose of 1080 (Connolly and Burns 1990). In conjunction with development of LPC's, we assessed environmental hazards posed by their use.

Compound 1080 is a highly toxic chemical used in predator and rodent control (Ward and Spencer 1947). Animals that directly ingest the compound usually die (primary poisoning). Secondary poisoning (secondary hazard) can occur when other animals scavenge on a victim of primary poisoning.

The danger of secondary poisoning has been reported for 1080 (Ward and Spencer 1947, Atzert 1971, and Hudson et al. 1984). However, more recent work indicates a possibly confusing overlap between primary and secondary hazards. Aulerich et al. (1987) indicated that some reported secondary hazards might actually have resulted from primary poisoning caused by unmetabolized 1080 from the gut of prey eaten by the predators. Additionally, recent and more specific work on secondary hazard sheds doubt on the generality of some early statements. For example, Eastland and Beasom (1986) found little danger of secondary poisoning in raccoons (*Procyon lotor*), oppossums (*Didelphis virginiana*), and striped skunks that ate coyotes killed with 4–400 mg 1080. Burns et al. (1986) found that various tissues from coyotes baited with 5–15 mg 1080 contained insufficient 1080 residue to produce secondary poisoning in coyotes, dogs, striped skunks, and black billed magpies (*Pica pica*). Hegdal et al. (1986) noted that raptors, except golden eagles, are less vulnerable to secondary poisoning than mammalian predators. Secondary hazard information on golden eagles is important because they were the most sensitive to 1080 among raptors and scavenging birds listed by Atzert (1971).

Our paper provides new information about potential secondary hazard to golden eagles and striped skunks exposed to known concentrations of 1080 in their diets. We assessed the hazard by feeding dietary concentrations of 1080 set at levels higher than those found in tissues of coyotes killed following attacks on sheep wearing LPC's.

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METHODS

Studies were conducted in September and October 1984 at Denver Wildlife Research Center facilities near Logan, Utah (skunks), and Denver, Colorado (eagles). Treatments were conducted with Compound 1080 (Tull Chemical Co., Oxford, Ala.)—a technical material with at least 90% sodium fluoroacetate active ingredient (ai).

Skunks.—Six skunks (5 M, 1 F) were live-trapped near Logan. Each was individually held outdoors in a 115- × 70- × 80-cm cage. Based on body mass and genital development, the skunks were considered adults, with the possible exception of a male that weighed 2.3 kg when captured. They were maintained on commercial mink (*Mustela vison*) feed before and after exposure to 1080-treated diets. The feed (Fur Breeders Agric. Co-op Assoc., Logan, Ut.) contained 26% water, 21% fish, 12% cereal grains, 10% poultry offal, 8% chicken, 8% poultry meal, 7% turkey, 2% fat, and 6% miscellaneous. The test diet, formulated with 5 ppm (ai) 1080, was prepared by mixing measured amounts of 1080 solution with the mink feed. The total amount of food required for the treatment period was mixed at 1 time, frozen in individual packages for daily feeding, then thawed and fed as needed.

Skunks were observed during a 7-day pretreatment, a 5-day treatment, and a 3-day posttreatment period. They received food, test diet, and water ad libitum (changed daily). We measured food consumption daily, beginning 5 days before treatment and continuing through posttreatment observations. Skunks were placed on the treated diet immediately after the pretreatment period and were observed at least once daily for signs of intoxication. Signs of 1080 intoxication vary from progressive depression to violent epileptiform convulsions (Ward and Spencer 1947) and include respiratory, central nervous system, and muscle effects shown by dyspnea, ataxia, weakness, tremors, convulsions, and increased salivation, urination, and defecation (Hudson et al. 1984). Also, vomiting is an early characteristic sign in some animals (Atzert 1971). Skunks were weighed at the end of each observation period.

The Denver Wildlife Research Center analyzed samples of treated diets for 1080 by using the technique of Okuno et al. (1982) with minor modifications. Rather than 1 g, as specified, 2 g of each sample were placed in individual 25- × 150-mm screw-cap culture tubes. Forty mL of extraction solvent were added, and the capped tubes were placed into an ultrasonic bath for 30 minutes. Tubes were then centrifuged, and a 2-mL aliquot of the extract was removed. The aliquot was placed into a 15- × 110-mm screw-cap tube with 1.6 mL of water, and the procedure continued as specified.

Eagles.—The U.S. Fish and Wildlife Service obtained 6 golden eagles (5 M, 1 F) for the study from raptor rehabilitation centers. The eagles were all adults and in good health. They were held outdoors, separately, in 1.8- × 1.8- × 3.6-m chainlink cages with a log perch. The birds received fresh water ad libitum. We observed eagles for a 19-day pretreatment, a 5-day treatment, and a 5-day posttreatment period.

During pretreatment and posttreatment periods, each eagle received 300 g of pet food and 150 g of lamb or ewe muscle daily. We measured food consumption daily, except that during posttreatment the amount of sheep muscle eaten was sometimes estimated. During treatment, each eagle was offered 500 g of treated pet food formulated with 10 ppm (ai) 1080 daily, and no additional food was offered. The pet food (Qual-Pet, Inc., Evans, Colo.) contained 100% beef burger—18.0% crude protein, 4.0% crude fat, 75.0% moisture, and 1.5% maximum crude fiber. We prepared the test diet by (1) dissolving 5.75 mg of technical grade 1080 in a vial containing 5.0 mL deionized water, (2) flattening 500 g of pet food to form a 3.8-cm thick × 20.3-cm diameter round patty, (3) dimpling the top of the patty about 1.3-cm deep, (4) adding the 1080 solution to the dimpled areas, rinsing the vial, and adding the rinsings to the dimpled areas, (5) thoroughly folding and kneading the solution into the food, and (6) dividing the patty into 5 100-g balls. Each eagle received 5 100-g balls per day during the 5-day treatment period. We estimated consumption daily by counting recovered whole balls and by visually estimating the percentage of partially eaten ones.

Eagles were observed at least daily for treatment-related signs, as described above for skunks, and were weighed at the end of each period.

Table 1. Mass of skunks, amounts of food, and 1080 consumed during the pretreatment, treatment, and posttreatment periods (food contained 5 ppm Compound 1080 during the treatment period).

Period	Skunk mass (kg)		Food consumed (g/day)		1080 consumed (mg/day)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Pretreatment	3.7	0.29	431	22.5		
Treatment	3.2	0.35	342	21.9	1.7	0.11
Posttreatment	3.5	0.39	389	27.3		

Table 2. Mass of eagles, amounts of food, and 1080 consumed during the pretreatment, treatment, and posttreatment periods (food contained 10 ppm Compound 1080 during the treatment period).

Period	Eagle mass (kg)		Food consumed (g/day)		1080 consumed (mg/day)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Pretreatment	4.4	0.19	344	2.5		
Treatment	4.4	0.26	275	20.0	2.43	0.18
Posttreatment	4.4	0.20	243	16.4		

Samples of diet were collected and analyzed as described previously for skunks.

RESULTS

Skunks.—Duplicate analyses of the test diet for skunks averaged 4.1 ppm 1080, 18% below our intended concentration. Similarly, analysis of the eagle test diets showed an average of 7.7 ppm (n = 4) 1080, also below the intended concentration.

Based on the nominal 5 ppm concentration, skunks consumed about 0.53 mg/kg/day of 1080 during the 5-day test period (Table 1). All skunks survived the test and showed no obvious signs of 1080 intoxication. During the test, all skunks decreased food intake, but no significant mass loss accompanied the reduced feeding ($t = 0.87$, 5 df, $P = 0.425$). After we removed 1080 from the diet, food consumption increased and significant mass gains from treatment levels were noted ($t = 4.78$, 5 df, $P = 0.005$).

Eagles.—After some initial sporadic feeding, eagles stabilized consumption of the pretreatment diet in an average of 3 days (range = 1–8 days) and little variation in daily intake was noted between stabilization and the end of the pretreatment period. Based on the nominal 10 ppm concentration, consumption of 1080 in the treated diet was about 0.54 mg/kg/day during the 5-day exposure period (Table 2). On Days 1 and 2 of the treatment period, average food intake for the 6 eagles was 329 and 400 g per eagle, respectively. On Days 3–5, average intake dropped to 198 g per eagle, but the downward trend was not significant ($r^2 = 0.616$, 3 df, $P = 0.12$).

Three eagles showed no obvious signs, whereas 3 others showed obvious reactions to 1080, including reduced feeding, fluffed feathers, loss of muscular strength and coordination (inability to mount perch), lethargy, and body tremors. Two eagles refused all treated food following onset of effects, but one ate reduced amounts; all 3 reduced feeding significantly during the treatment period ($r^2 = 0.893$, 3 df, $P = 0.015$).

Changes in body mass were not consistent among eagles ($F = 0.01$; 2,15 df; $P = 0.99$): three gained and three lost mass during the 1080 treatment; two lost, two gained, and two maintained their mass during posttreatment.

Based on returned strength and coordination, the absence of tremors, and renewed feeding activity, affected birds returned to pretreatment condition by the fourth day of the posttreatment period, and no further complications were observed.

DISCUSSION

Although assay concentrations of 1080 in treated diets were lower than expected, the skunk diet was nearly double and the eagle diet more than triple the highest levels of 1080 detected in coyote muscle tissue (0.93 ppm) and vomitus or stomach contents (2.30 ppm) from coyotes killed by 1080 from LPC's on sheep (R. J. Burns, unpubl. rep., U.S. Fish Wildl. Serv., Denver Wildl. Res. Cent., 1984).

No skunks died or showed signs of 1080 effects other than reduced feeding and suppressed mass. Burns et al. (1986) also detected no secondary hazards to striped skunks, domestic dogs, coyotes, or magpies that fed on coyotes killed by 5–15 mg of 1080, and Eastland and Beasom (1986) reported secondary hazard to striped skunks unlikely from toxic collars (LPC's) or 4-mg 1080 baits.

Eastland and Beasom (1987) reported the median lethal dose (LD_{50}) of 1080 for striped skunks in an acute toxicity test at 0.35 mg/kg with a 95% confidence interval of 0.21–0.54 mg/kg. Our skunks consumed an average of 0.53 mg/kg/day—a quantity near the upper confidence limit—but did not die, probably because the 1080 came in food instead of in a lone dose on an empty stomach. These results were similar to those of Hornshaw et al. (1986) who found that the upper daily limit in consumption of 1080-treated diets by mink and European ferrets (*Mustela putorius furo*) was approximately their respective LD_{50}'s; and that mink and ferrets, like skunks in our test, reduced feeding and lost mass on 1080-treated diets.

Some eagles showed signs of 1080 intoxication, which might be interpreted as an environmental hazard. However, the diet was treated with substantially more 1080 than has been found in coyotes killed by LPC's. The LD_{50} for 1080 in golden eagles was estimated by Ward and Spencer (1947) at 1.25–5.00 mg/kg and by Hudson et al. (1984) at 3.54 mg/kg with a 95% confidence interval of 0.49–25.10. In our tests, eagles consumed an average of 0.54 mg/kg/day during the 5-day treatment, well below the estimated LD_{50}. Our results indicated a wide range of tolerance for 1080 among eagles, substantiating the finding cited above. This repeated demonstration of a wide range in response is important because whether or not eagles suffer secondary hazard from 1080 is controversial, and the wide range in response probably explains at least part of why secondary hazards to 1080 in eagles might or might not occur.

Under our test conditions, skunks and some eagles reduced food consumption or stopped feeding on 1080-treated diets. Such a voluntary reduction in intake could provide some protection to these scavengers in the field in the unlikely event that they encountered 1080 concentrations in dead coyotes that reached hazardous levels. We conclude that coyotes killed by LPC's present little, if any, secondary hazard to striped skunks or golden eagles.

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